OAK RIDGE National Laboratory

ORNL Report on Nuclear Evaluation Work for FY18

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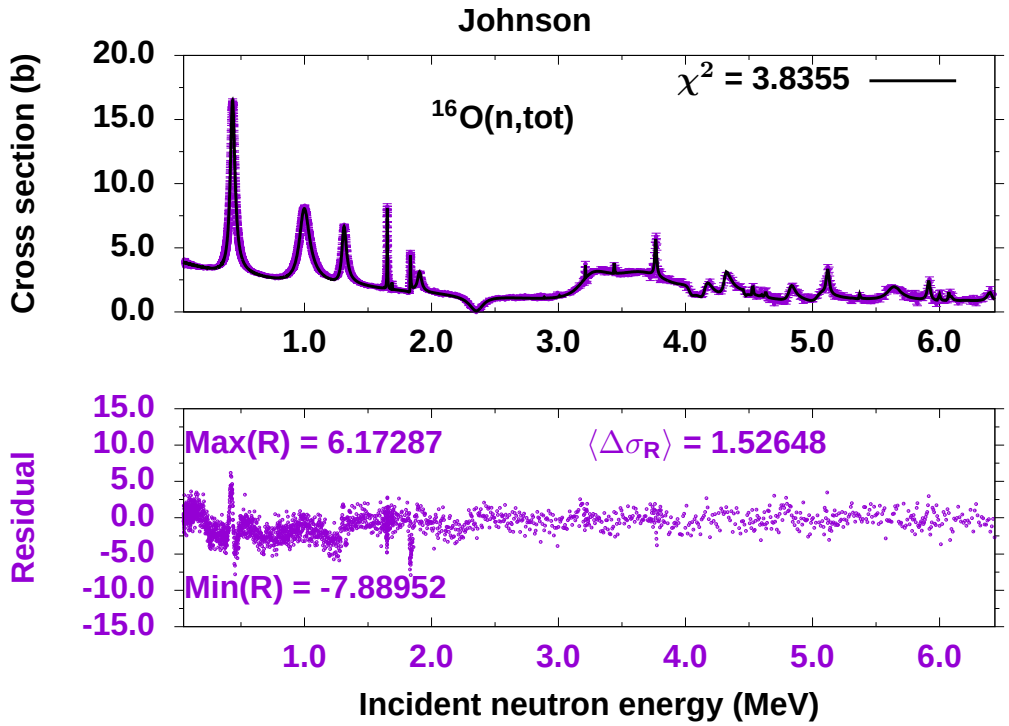
OUTLINE

- **Summary of the following resonance parameter evaluations**
  - ^{16}O
  - $^{28,29,30}Si$
  - ^{51}V
  - $^{140,142}Ce$
  - $^{155,156,157,158,160}Gd$
  - $^{156,158,160,161,162,163,164}Dy$
  - ^{233}U
- **Measurements and additional tasks**
- **Acknowledgments**

^{16}O evaluation

- The evaluation work builds on a comprehensive resonance analysis that was initiated in FY16[1] and updated through FY17/18[2]
- This evaluation work is currently part of the series of **INDEN meetings** (May 2019) on light nuclei evaluations



[1]Notes on the consistency of ^{16}O(n,α) cross sections
[2]ORNL contribution to ENDF/B-VIII.0 and progress on light nuclei evaluations

^{28,29,30}Si evaluations

- The resonance parameter evaluation of 3 silicon isotopes ^{28,29,30}Si (ORNL/TM-2001/271) was performed for NCSP. For the first time, the direct capture component (DC) was included and, because of the difficulty, at that time, to process ENDF files containing DC contributions, the evaluations were never included in the ENDF/B-VII.1 library
- In the thermal energy range the DC contribution is not negligible (about 40%)
- The evaluation of the ^{28}Si(n_{th},γ) cross section was controversial due to the discrepant values found in the experimental database

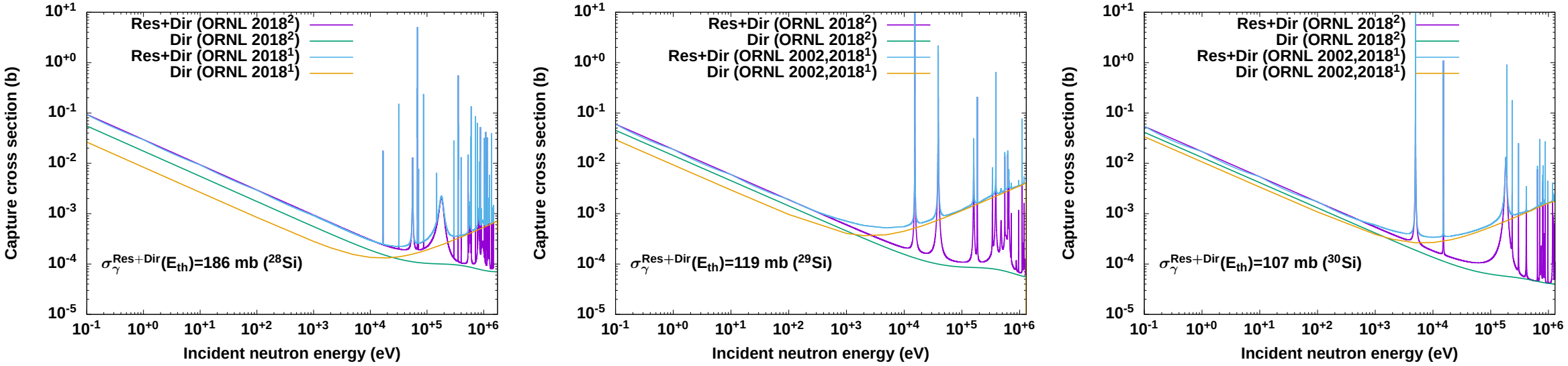
Table 1: Measured and evaluated ^{28}Si(n_{th},γ) cross sections (in mb). The direct and resonance component to the total capture cross section is shown when possible.

Author (Year)	**Value (mb)**	σ_γ**(res)**	σ_γ**(dir)**
Islam (1990)	207±4		
Kennett (1992)	171±3		
Raman (1992)	169±4	34.9[a]	134.1[b]
Mughabghab (2006)	177±4	45[a]	132
ORNL (2002)	168.9	103.1	65.8
IAEA (2007)	186±3	N/A	N/A
ENDF/B-VIII.0 (2018)	169.1	169.1	0.00
ORNL (2018[1])	184.5	131.9	52.6
ORNL (2018[2])	186.0	76.0	110.0

[a]Computed by subtraction.
[b]Computed from the values reported in the 'G+V' column for ^{28}Si in Table V of Phys. Rev. C**46**, 972 (1992).

^{28,29,30}Si evaluations (continued)

- New calculations (in green) with the CUPIDO code[3] were performed by using a complex optical potential consistently accounting for the absorption cross sections
- Old calculations (in yellow) seemed to have a nonphysical behavior above 10 keV

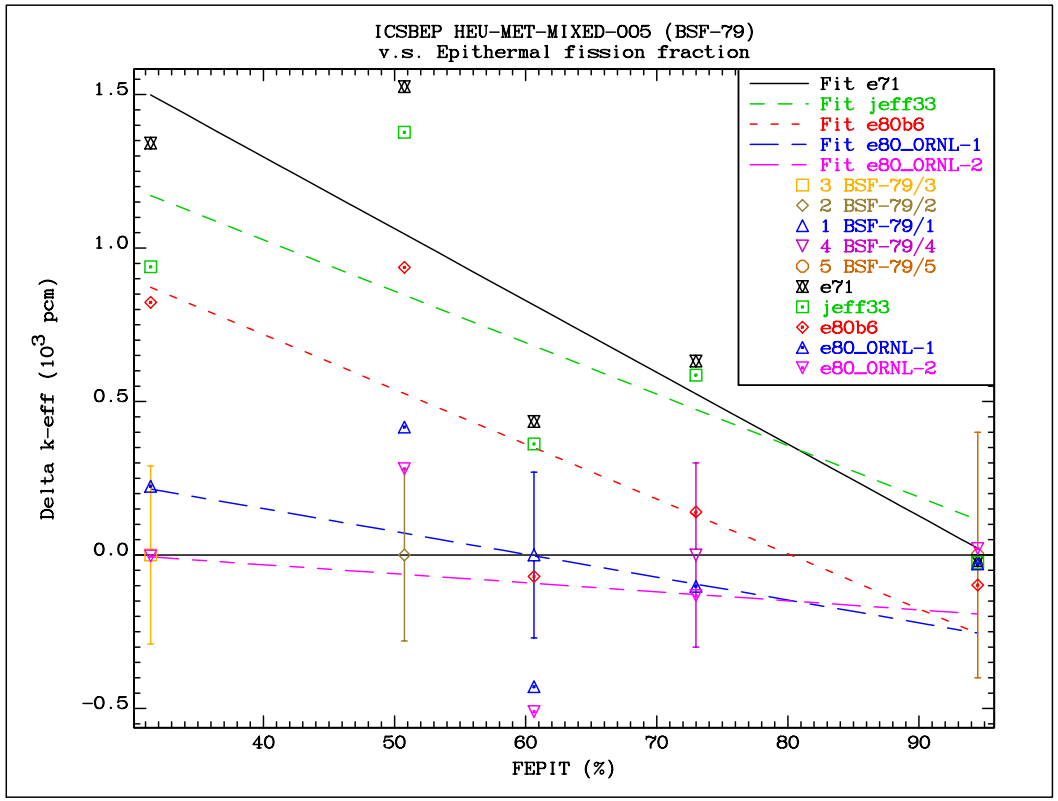


- The use of better physics to describe the direct capture component improved the overall agreement with integral measurements
- Work publicly available in ORNL/LTR-2018/1044

[3]G. Arbanas, F. S. Dietrich, and A. K. Kerman. Direct-semidirect thermal neutron capture calculations. Technical Report UCRL-PROC-217859 (2005).

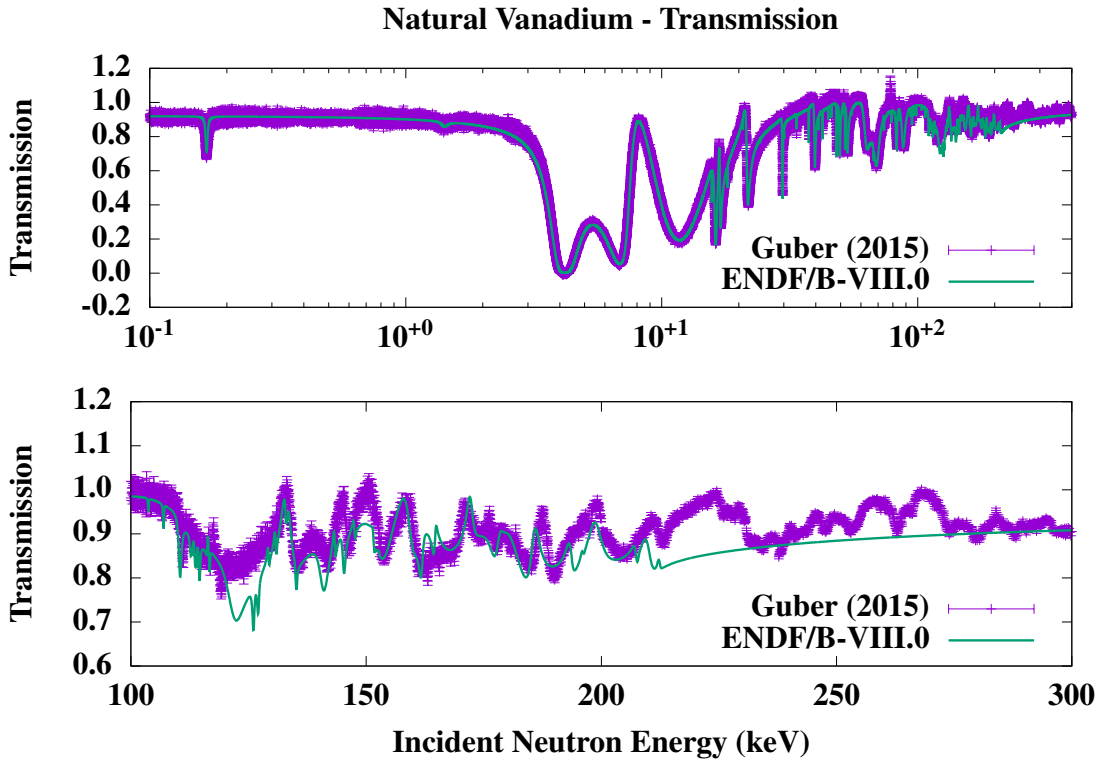
^{28,29,30}Si evaluations (continued)

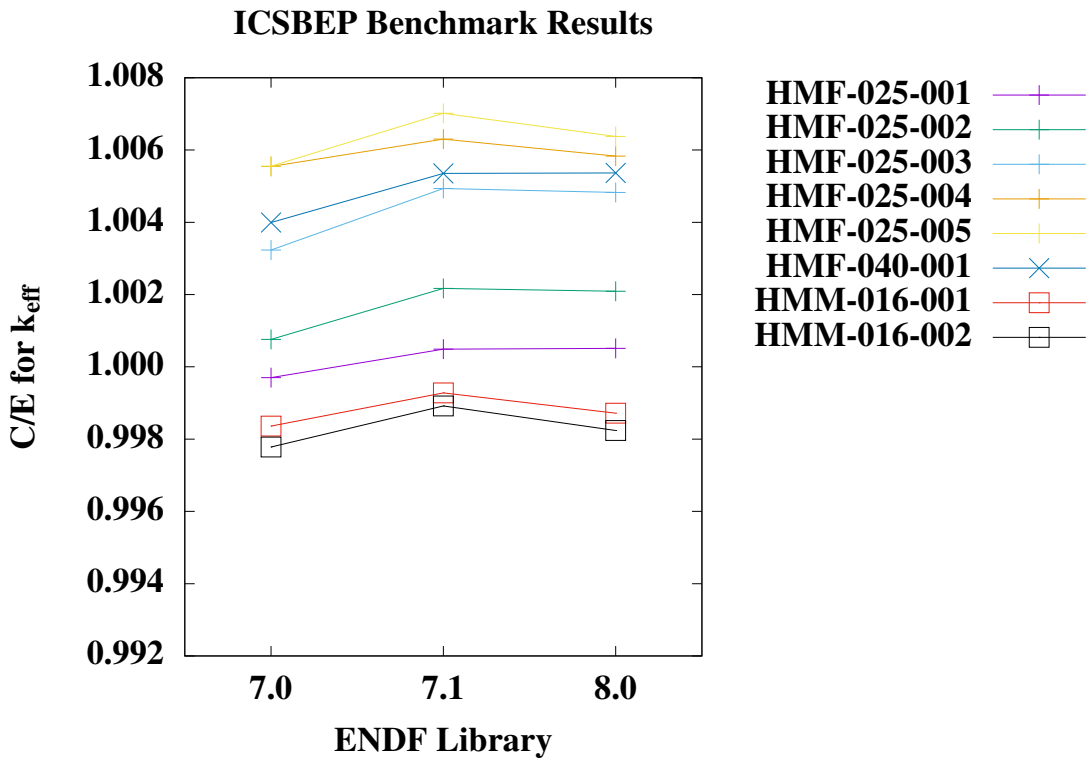
- The increased value of the $^{28}Si(n_{th},\gamma)$ cross sections induces a reduction of about 800 pcm in the thermal assemblies (e.g. HEU-MET-MIXED-005.3 or BSF-79/3 in yellow), showing that the criticality is independent of the epithermal fraction spectra.



^{51}V evaluation

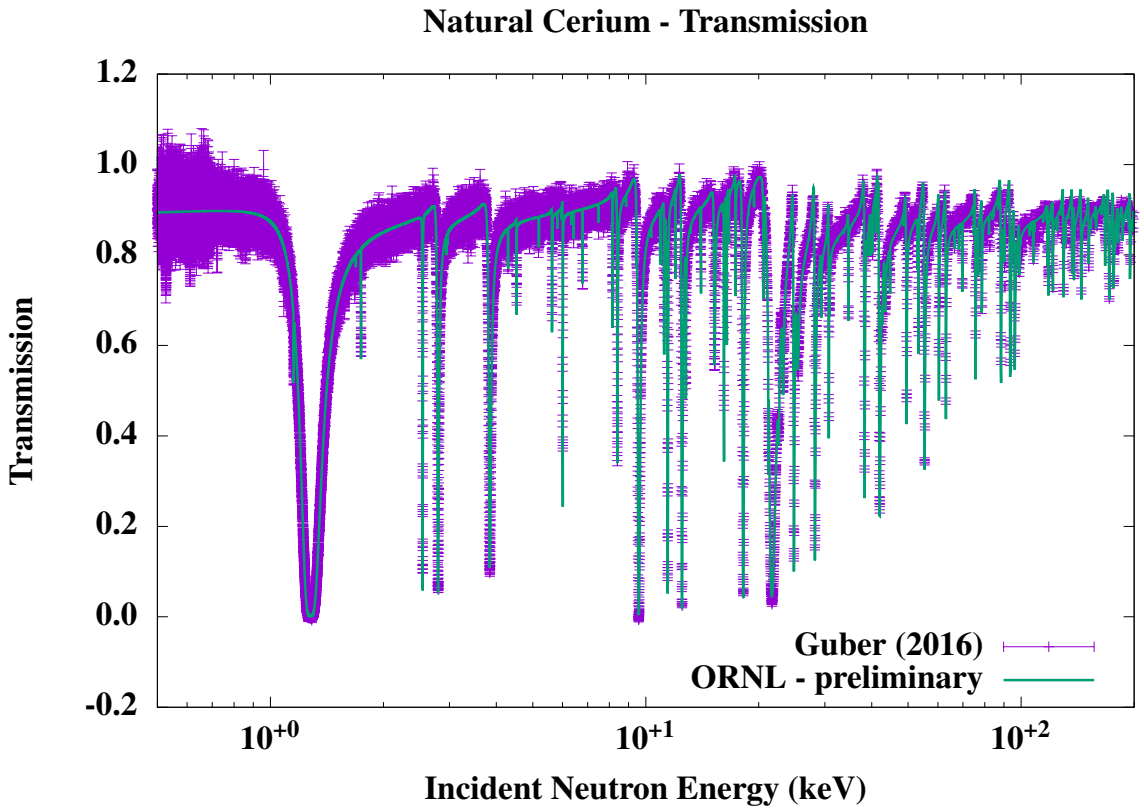
- Current resonance parameter evaluation in the ENDF/B-VIII.0 library is up to 100 keV. The plan is to extend it up to 300 keV based on the newly measured data (Guber 2018)
- Analysis on additional available experimental data including the minor ^{50}V isotope is in progress. Although ^{51}V (99.75%) is the dominant isotope, there are large contributions from low-lying resonances of ^{50}V (0.25%)

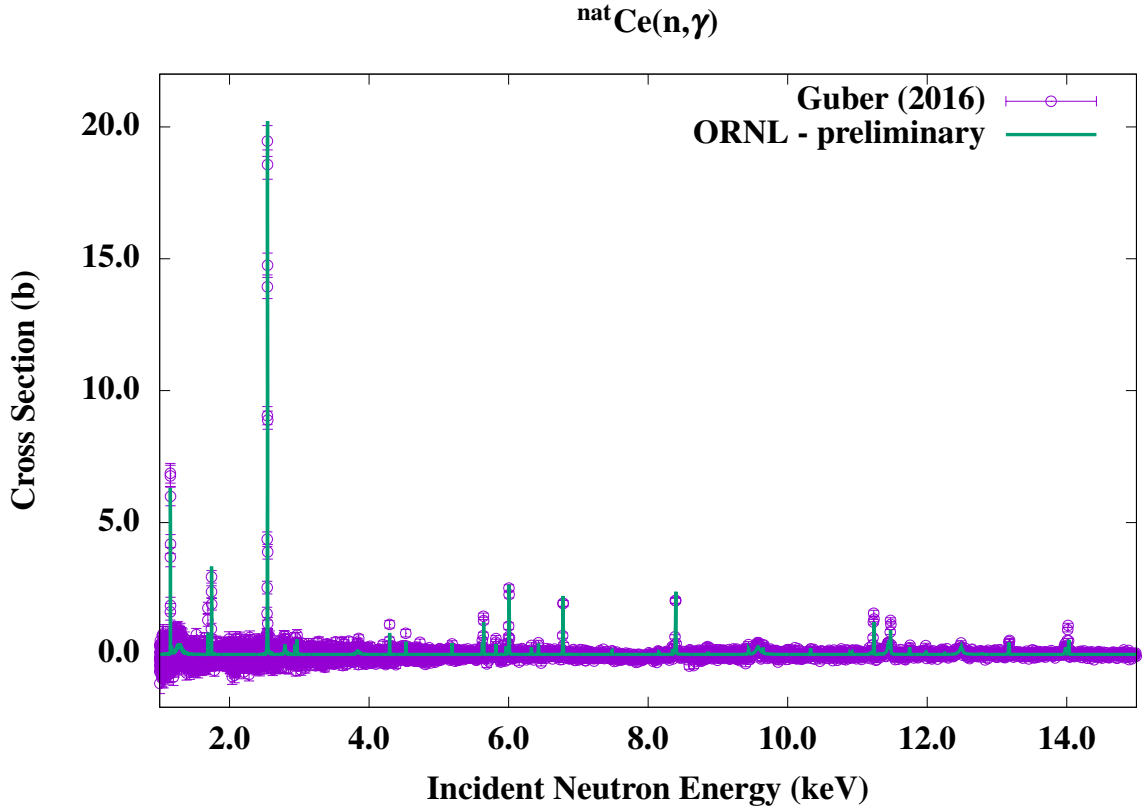




^{140,142}Ce evaluations

- R-matrix analysis on transmission and capture data for natural sample is in progress.
- In the process of measuring enriched ^{142}Ce data at the GELINA facility

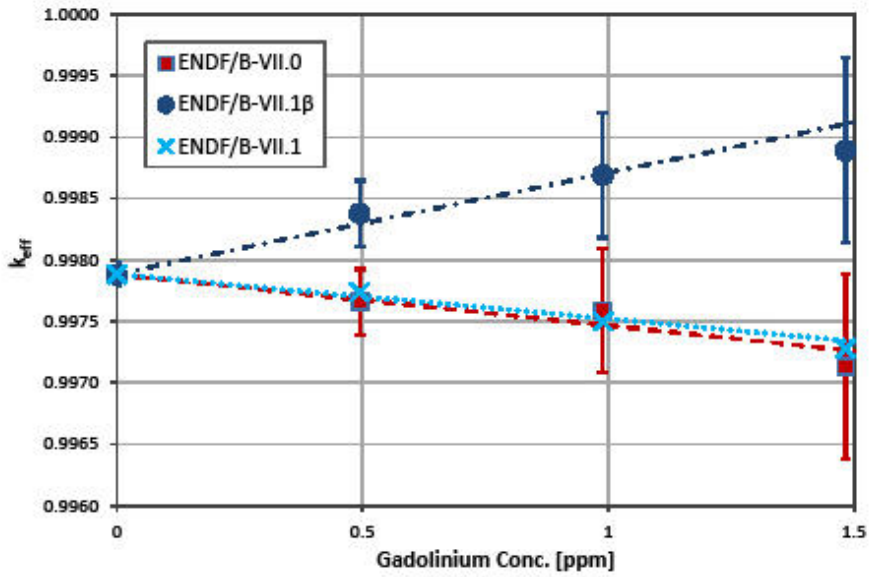




^{155,156,157,158,160}Gd evaluations

Status – Differential measurements

- Current evaluation is discrepant with average cross section measurements from Karlsruhe
- Experimental measurements from the RPI Gaerttner LINAC Center suggest discrepancies of **up to 9%** in the thermal cross section values

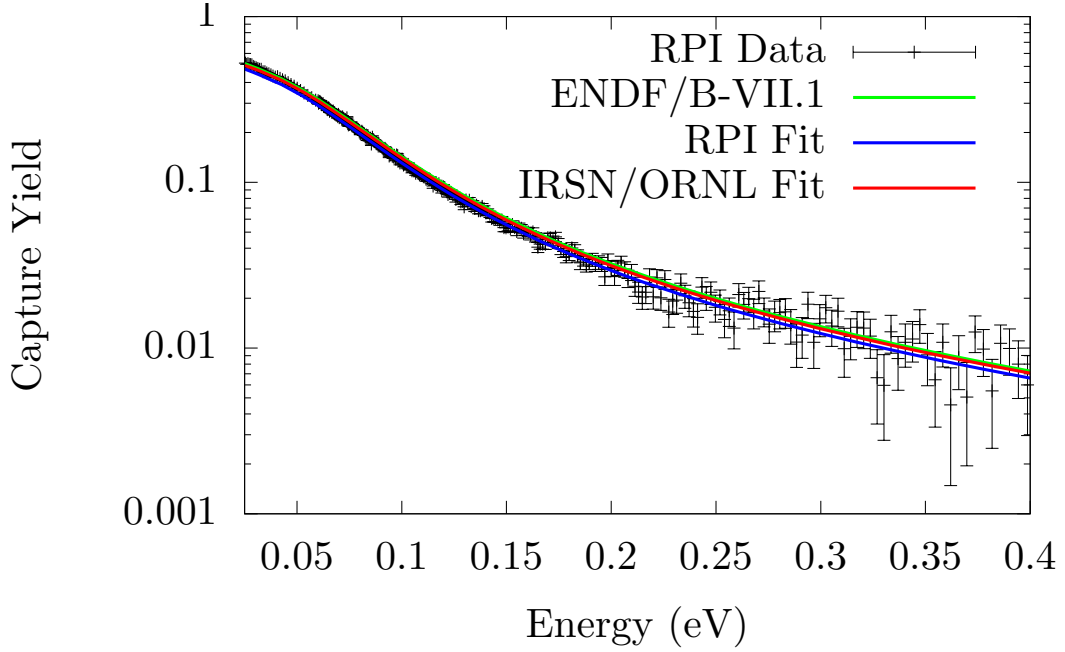


Status – Integral measurements

- Lack of a clear validation case in ICSBEP for Gadolinium (see BJ Marshal, “The Case For and Against a Gadolinium Bias in SCALE: Opening Arguments,” ANS Annual Meeting, June 20, 2018, Philadelphia, PA)
- AECL ZED-2 critical facility measured k_{eff} vs Gd concentration: under-prediction of the capture cross section in the **ENDF/B-VII.1**β release and over-prediction in **ENDF/B-VII.1** (Not part of ICSBEP)

^{155,156,157,158,160}Gd evaluations

- IRSN (Leal) and ORNL (Sobes) are partnering to complete a new evaluation for the five major isotopes of Gadolinium
- The new evaluation seeks to resolve some of the discrepancies between the experimentally measured data
- The new evaluation will deliver a covariance matrix with cross-isotope covariances that are a natural byproduct of the analysis of natural samples of gadolinium
- Beta-testing release expected in July of 2019. Full evaluation planned to be complete by end of FY19.



^{156,158,160,161,162,163,164}Dy evaluations

- **Set of Dy resonance parameter evaluations completed and submitted to the ENDF/B repository**

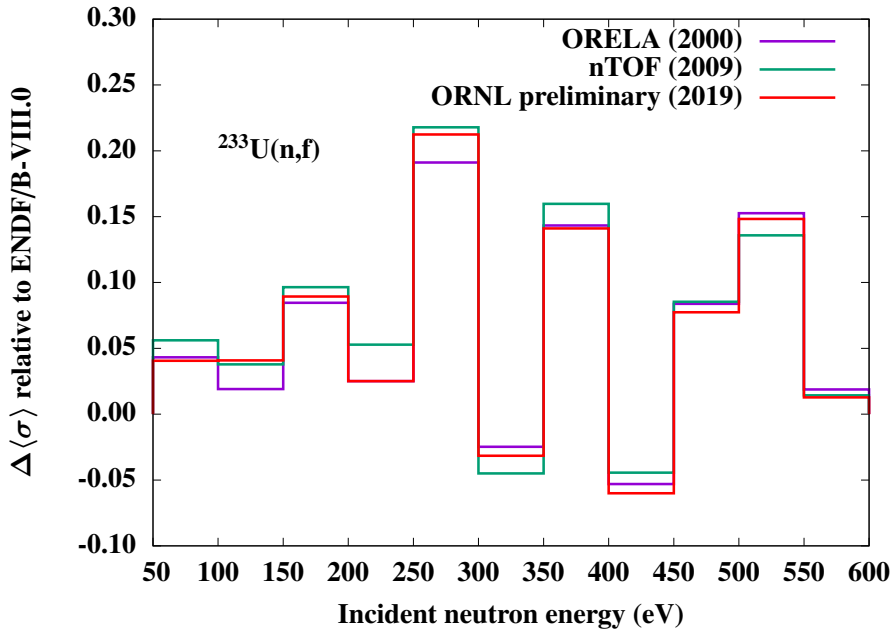
Author	Isotope	Energy range analyzed	Main features
Liou (1975)	^{160}Dy	15 eV–2 keV	Transmission; ToF 202.05 m; 0.000881 a/b
	^{161}Dy	15 eV–1 keV	Transmission; ToF 202.05 m; 0.001644 and 0.007451 a/b
	^{162}Dy	15 eV–5 keV	Transmission; ToF 202.05 m; 0.001533 and 0.007934 a/b
	^{163}Dy	15 eV–1 keV	Transmission; ToF 202.05 m; 0.001403 a/b
	^{164}Dy	15 eV–7 keV	Transmission; ToF 202.05 m; 0.001054 and 0.002337 a/b
Shin (2017)	^{161}Dy	12 eV–1 keV	Capture yield; ToF 25.56 m; 0.0006359 a/b
	^{162}Dy	10 eV–1 keV	Capture yield; ToF 25.56 m; 0.0006445 a/b
	^{163}Dy	10 eV–1 keV	Capture yield; ToF 25.56 m; 0.0006503 a/b
	^{164}Dy	10 eV–1 keV	Capture yield; ToF 25.56 m; 0.0006196 a/b
Block (2017)	^{nat}Dy	10^{-2}–20 eV	Transmission; ToF 14.97 m; 0.001610 a/b
	^{nat}Dy	10^{-2}–20 eV	Capture yield; ToF 25.44 m; 0.0007840 a/b
	^{nat}Dy	10 eV–1 keV	Capture yield; ToF 25.56 m; 0.0016304 a/b

- Review of old existing Liou's transmission data sets showed several issues
  - The large number of negative values in the ^{160,163,164}Dy total cross sections imply an over correction of the background contribution
  - The measurements were performed on oxide samples (DY_2O_3), but the number of atoms/barn reported seems related to the specific enriched isotope. This affected our ability to correctly calculate the total number of atoms/barn of the sample
  - Several "black" resonances[4] were reported and no uncertainty analysis was reported

[4] Energy levels for which there is no transmission of neutrons or, vice versa, the neutron absorption is maximum.

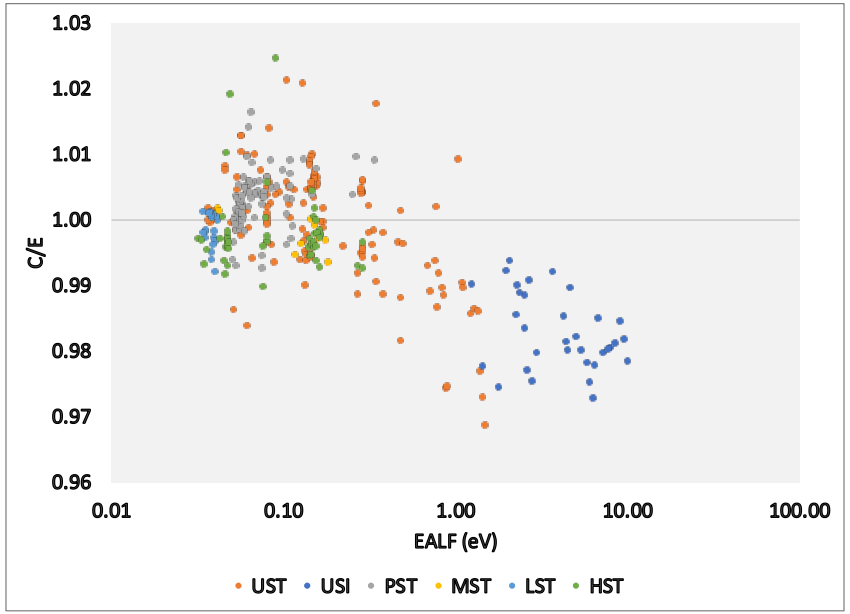
^{233}U evaluation

- Precise ^{233}U(n,f) and ^{233}U(n,tot) cross section measurements performed at ORELA(1997–2000) built the basis of the ORNL evaluation (2001) included in ENDF/B-VII.1 library (2006). However, **only the shape of the ORELA fission cross sections was used**
  - The newly measured fission data were normalized to consistently fit the total cross section and the existing capture measurements
  - A recent ^{233}U(n,f) cross section measurement performed at the nTOF facility (Phys. Rev. C80, 044604 (2009)) shows agreement (within 2%) with the ORELA fission data



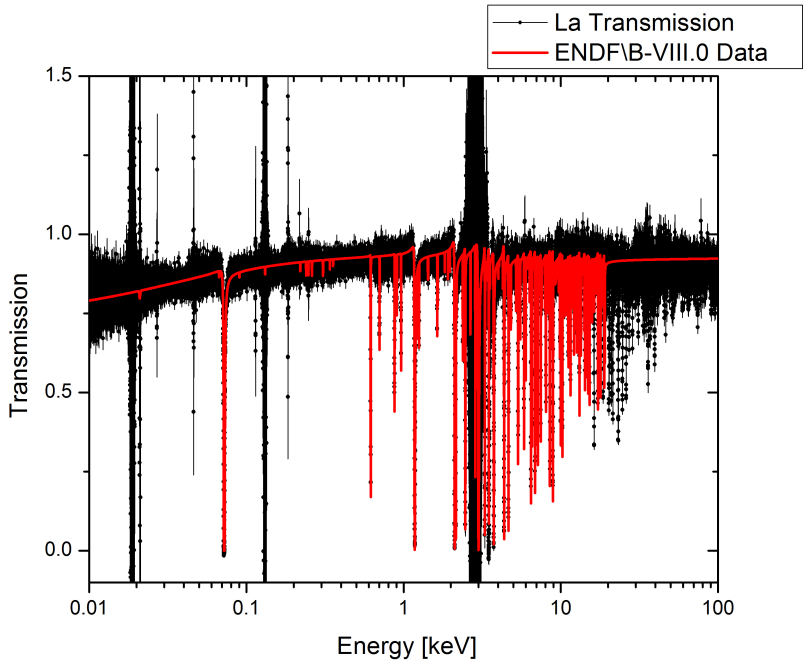
^{233}U evaluation (continued)

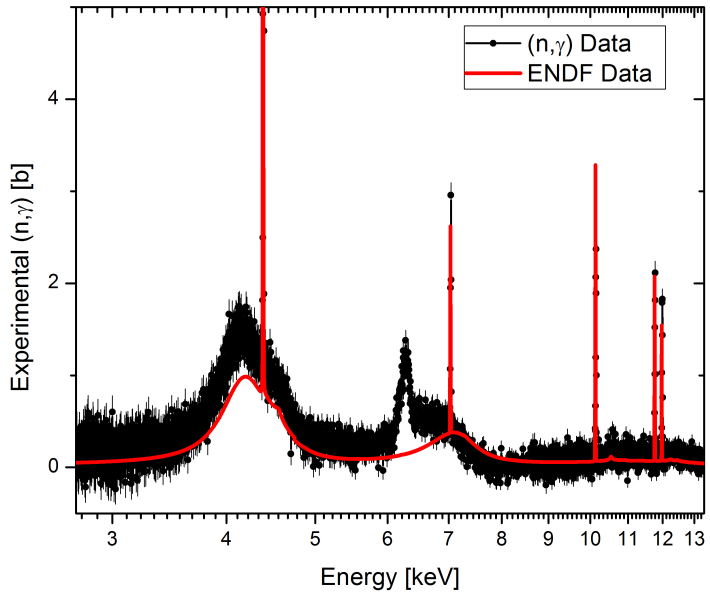
- To generate an updated RRR evaluation fitting the ORELA measured fission data (preliminary results shown on slide 12)
- To improve poor performance of the benchmark calculations by improving the evaluation work into the URR region.
- The evaluation in the URR will include:
  - Sorting of the available experimental data and the generation of average resonance parameters
  - Self-shielding corrections (SESH code)



Measurements and additional tasks

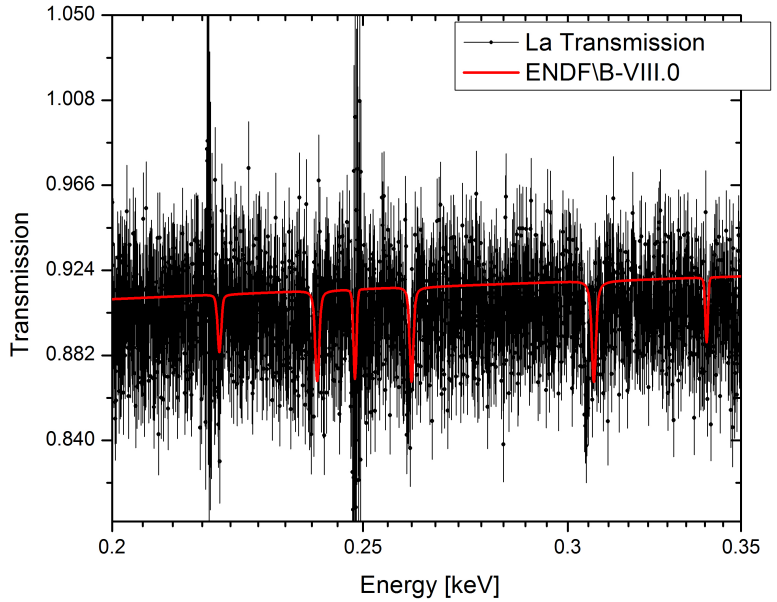
- ^{51}V, ^{139}La, and ^{181}Ta measurements completed within the NDCS program (APPENDIX B five years plan)
- Transmission and capture measurements on ^{51}V and ^{139}La samples were performed at the GELINA facility
- Transmission and capture measurements on ^{181}Ta sample were performed in the RRR/URR at RPI. Evaluation work in the RRR was recently initiated by D. Barry by using high resolution data measured at ORELA by J. Harvey
- Support to RRR (and URR for ^{181}Ta) evaluations started in FY19 (RPI/ORNL)





Measurements and additional tasks (lanthanum)

- Measurements used metallic samples of ^{nat}La - ^{138}La(0.09%) and ^{139}La(99.91%) - with different thickness
- Transmission experiments (50 m flight path) with different samples used a Li-glass detector. Neutron capture experiments (60 m flight path) used C_6D_6 detectors
- Experiments are made with different background filter combinations
- Capture and transmission experiments have been finalized and data sorting started



Acknowledgments

Work supported by the US Department of Energy (DOE), Nuclear Criticality Safety Program (NCSP) funded and managed by the National Nuclear Security Administration (NNSA) for DOE.

Thank you!